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**Docket No.: 11-355382**

## BACKGROUND OF THE INVENTION

5       The present invention relates generally to a packet switch.  
More particularly, the invention relates to a packet switch  
for scheduling between input and output in a packet switching  
system and realizing the scheduling.

10           In the recent packet switching system, an input buffer type switch having N in number of inputs and N in number of outputs (N is natural number: the same shall be applied hereinafter) and, in which each input portion has N in number of virtual output queuing (VOQ), is typically employed.

The input port has a construction of a virtual output queuing (VOQ) 52. As the switching element 54, a cross-bar switch is typically employed. The scheduler 50 employs a



Upon generation of the connection grant information, each distributed scheduling modules 51-1 to 51-N determine permission and rejection of connection of the individual input port to the output port.

- 5           The output port granted connection by a certain distributed scheduling module 51-n ( $n$  is natural number  $1 \leq n \leq N$ ) is a port "reserved" for other distributed scheduling module for another distributed scheduling module 51-m ( $m \neq n$ ) and becomes the port impossible to issue connection grant.
- 10   Hereinafter, operation for determining connection grant to the output port by certain scheduling module is expressed as "reserve output port".

- As a distributed type scheduling algorithm of the packet switch, there is a round robin greedy scheduling (RRGS) algorithm
- 15   reported in A. Smiljanic, R. Fan and G. Ramanurthy "RRGS\* Round Robin Greedy Scheduling for Electric/Optical Terabit Switches" in Globecom, 1999.

- In case of the scheduler employing the RRGS algorithm, the distributed scheduling module is connected in ring form
- 20   for transferring message between adjacent distributed scheduling module. In the RRGS algorithm, reservation (connection grant determination) of time slot to be an object of the distributed scheduling module is performed to transfer the resultant information to the next distributed scheduling

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module. In order to ease message transfer speed demand condition, RRGs introduces a pipeline function. A reservation process of the time slot is completed upon completion of message transfer between respective distribution scheduling modules in one cycle.

5 On the other hand,  $N$  in number of distributed scheduling module makes reservation for at least  $N$  slots ahead of the current slot. Furthermore, the RRGs algorithm progresses the reservation process for  $N$  time slots with shifting phase per one time slot.

10 On the other hand, as a modification of the RRGs algorithm, it can be considered an algorithm, in which reservation process for a plurality of time slots are started simultaneously from respectively different distributed scheduling modules to progress for completing simultaneously. Such algorithm is  
15 referred to as a framed RRGs.

Fig. 12 is a block diagram showing a construction of the packet switch with the distributed type scheduler employing the RRGs and framed RRGs. In Fig. 12, as an example, a system having four ports ( $N = 4$ ). In Fig. 12, the scheduler 1 is  
20 constructed with input modules (IM) 10-1 to 10-4 for performing distributed type scheduling. For each module 10- $i$  ( $i = 1$  to 4), a frame pulse (FP) 21 indicative of the leading end of the frame and a super frame pulse (SuperFP) indicative of the leading end of a super frame. Each module 10- $i$  operates in synchronism  
25 with the frame pulse 21 or the super frame pulse 22.

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10.

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in module number is #1  $\rightarrow$  #2  $\rightarrow$  #3  $\rightarrow$  #4  $\rightarrow$  #1  $\rightarrow$  #2 ...

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The connection request of each input port is 1 when the request is present and 0 when no request is present. The connection grant information (reserve information) is 1 when connection is granted (reserved) and 0 when connection is inhibited (non-reserved). The reserved output port information is 1 as reserved and 0 as not reserved.

In the shown example one frame is consist of four time slots and the frame pulse 21 is input in four time slot period. Also, the super frame pulse 2 does not be used in the shown example.

In Fig. 13, when the frame pulse 21 is input to the modules 10-1 to 10-4 at a time slot TS1, the module 10-1 at first makes determination for the connection grant information of the input port 1 for the time slot TS1 of the next frame. Since this is the first determination, the reserved output port information of respective output ports are (0, 0, 0, 0) from the output port 1 to the output port 4 in sequential order. It is assumed that the connection request of the input port 1 is (0, 1, 0, 1) from the output port 1 to the output port 4 in sequential order. When the module 10-1 selects the output port 2, the module 10-1 stores the output port 2 as the connection grant information at the time slot TS1 for the next frame. Then, the reserved output port information (0, 1, 0, 0) is notified to the module 10-2.

Subsequently, at the time slot TS2, the module 10-2

determines the connection grant information of the input port 2 at the time slot TS1 for the next frame. Then, the module 10-2 receives the reserved output port information (0, 1, 0, 0). It is assumed that the connection request of the input port 2 is (0, 1, 1, 1), since the connection request cannot be assigned to the output port 2 since the output port 2 has already been reserved, the module 10-2 rejects connection request to the output port 2 for selecting the output port granting the connection request among the output ports 3 and 4. Here, it is assumed that the output port 3 is selected for granting the connection request. Then, the module 10-2 stores the output port 3 as the connection grant information at the time slot TS5 to notify the reserved output port information (0, 1, 1, 0) to the module 10-3.

Then, at time slot TS3, the module 10-3 and at time slot TS4, the module 10-4 determine the connection grant information at time slot TS1 for the next frame. At the timing where the time slot TS4 is completed, respective modules have the connection grant information at the time slot TS1 for the next frame, 4 x 4 connection grant information at the time slot TS1 for the next frame is fixed.

Furthermore, in the foregoing process procedure, at the time slot TS1, the module other than the module 10-1 starts "reservation" for respectively different time slots. For example, the module 10-2 starts reservation for time slot TS4

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for the next frame, the module 10-3 starts reservation for time slot TS3 for the next frame and the module 10-4 starts reservation for the time slot TS2.

Respective modules performs process of respective reserved time slots at the relevant time slots, the reserved output information of the relevant reserved time slot is transferred to respective modules of next stages to perform scheduling process so that respective modules 10-1 to 10-4 will not have non-operation period. At a timing where the time slot TS4 is completed, respective modules have the connection grant information from the time slots TS1 to TS4 in the next frame, 4 x 4 connection grant information from the time slots TS1 to TS4 of the next frame is fixed.

Fig. 14 is an illustration showing the order of reservation (connection grant determination) of respective module. Fig. 14 shows the example of the case of 4 x 4 scheduler. Horizontal axis represents a time, in which one frame is consisted of four time slots. Vertical axis represent physical number of the modules. Transfer direction of the reserved output port information is #1 → #2 → #3 → #4 → #1 → #2 ... in physical number of the modules. Figures in the matrix represent number of the time slot in the next frame to reserve.

As shown in Fig. 14, the module having the physical number #1 is the leading module (time slot TS1) of the frame and starts from reservation of the time slot TS1 of the next frame.

Similarly, the module of the physical number #2 starts reservation from the time slot TS4, the module of the physical number #3 starts reservation from the time slot TS3, and the module of the physical number #4 starts reservation from the time slot TS2.

When the foregoing conventional algorithm is employed, the following problems are encountered.

At first, when more than or equal to two and less than total number of ports input uniform traffic, ratio of obtaining of reservation (connection request process) between the ports becomes unfairness. In RRGs, since the scheduler having chance of making reservation at earlier timing on the pipeline has higher preference in reservation, probability of obtaining chance of connection becomes higher. Accordingly, the scheduler having earlier reservation chance is absolutely dominant in making reservation. This characteristics is caused by fixed connection topology of the modules. For this characteristics, unfairness is caused in obtaining chance of connection between adjacent ports.

In this respect, discussion will be given in terms of example of Figs. 12 and 14. It is assumed that data to the output port 3 is accumulated in the input ports 1 and 2, and no other data is present. In this case, a connection request from the input port 1 to the output port 3 and a connection request from the input port 2 to the output port 3 are transmitted to every

However, referring to Fig. 14, in the scheduler, the input port 2 may have a chance to obtain reservation for the output port 3 at earlier timing than the input port 1 at reservation in the time slot 4, and in other time slots, the input port 1 may have a chance to obtain reservation for the output port 3 at earlier timing than the input port 2. Accordingly, the process ratio becomes 75% at the input port 1 side and 25% at the input port 2 side. In general, considering the foregoing phenomenon in the adjacent two ports among N ports, obtaining ratio of port on upstream side and downstream side becomes  $N-1 : 1$ . Degree of unfairness is increased according to increasing of number of ports. This problem occur in adjacent two or more and  $N-1$  or less ports. When number of adjacent ports is m, the obtaining ratio of the port between the most upstream side port and other port is  $N-m+1 : 1 : \dots : 1$  (number of term is m).

Next, the second problem is occurrence of unfairness between the ports in terms of process delay (a period to connection grant response for the connection request) in the same frame. In the shown example, the starting order of the time slot to be reserved in the frame by respective modules is fixed. Therefore, in certain module, the time slot given the chance of reservation at the first timing is the leading time slot in the frame, and in other module, the time slot given the chance

of reservation at the first timing becomes the last time slot in the frame.

As set forth above, in the conventional algorithm, the scheduler having earlier reservation chance at earlier timing on the pipeline has higher probability. Therefore, the scheduler having the earliest reservation chance is absolutely dominant in making reservation. When the transmission timing of the time slot having the first reservation chance in each module 10 is fixed, time differences to reservation for the connection request arriving at the same timing between the modules become unfair to cause unfairness in delay timing resulting in unfairness of the cell transmission.

In this point, an example of the case of Figs. 12 and 14 set forth above will be discussed. Considering reservation of connection of respective modules 10-1 to 10-4 in the time slot TS1 as the leading time slot of the frame, the module 10-1 performs reservation of the time slot TS1 of the next frame at the leading end of the frame. The module 10-2 performs reservation of the time slot TS4 of the next frame at the leading end of the frame. The module 10-1 may make reservation of the slot at the earliest timing. On the other hand, the module 10-2 makes reservation of the time slot at the latest timing. For the connection request arriving at the same timing, the module 10-1 may make reservation of the time slot at earlier timing than other modules 10-2 to 10-4.

SUMMARY OF THE INVENTION

The present invention has been worked out for solving the problem in the prior art. It is therefore an object of the present invention to provide a packet switching which can resolve  
5 unfairness between ports by a simple optional function and a packet switching method in the packet switch.

According to the first aspect of the invention, a packet switch for controlling flow of data in a network, comprises:

a plurality of input ports;  
10 a plurality of output ports;

a scheduler having N (natural number) in number of input port scheduling modules reserving a particular input port among the plurality of input ports for feeding data to a designated output port among the plurality of output ports and determining  
15 connecting condition between the input port and the output port,

in the scheduler, each of the scheduling module receiving reservation condition information of a certain time slot from the scheduling module in the preceding stage and determining permission or rejection of reservation of packet transmission  
20 from the input port scheduling module in the reservation time slot, per time slot

the scheduling module including

means for reservation of packet transmission referring the reservation condition information received from the  
25 scheduling module in the preceding stage and the reservation

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request of own scheduling module and transimitting the result of the reservation of packet transimission to the scheduling module in the next stage ;

means for defining a frame consisted of N in number of  
5 time slots and performing reservation in N time slots in a next frame in a current frame period;

means, in the current scheduling module, for receiving said reservation condition information from the preceding scheduling module;

10 means, in the current scheduling module, for preliminarily determining a future time slot to access one of said plurality of output ports as the particular time slot in the next frame;

means for selecting one of said plurality of output ports for reservation for transmitting in said future time slot;

15 means for making judgment whether said future time slot has already been reserved by other scheduling module;

means for making reservation of said future time slot when said future time slot is not reserved by other scheduling module and putting information indicative that said future time  
20 slot is reserved in said reservation condition information;

means for transferring said reservation condition information to next scheduling module,

considering in viewpoint of reservation process in the time slot,

25 said reservation process being initiated simultaneously

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said input port scheduling module having

reservation order varying means for varying order of said

10 reservation by said plurality of scheduling module,

A plurality of scheduling modules performs said reservation in an order corresponding to logical connection order relative to other modules, said reservation order varying means varies a connection topology of said plurality of scheduling modules. The reservation order varying means includes a switch performing switching operation for varying logical connecting condition of said plurality of scheduling modules and a table storing control data for controlling switching operation of said switch. Physical connection between said plurality of scheduling module and said switch is an electrical connection or an optical connection.

25           The table is provided in each of said plurality of

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scheduling modules. In the alternative the table is provide  
in common for said plurality of scheduling modules. The  
control data is data for controlling switching operation of  
said switch for varying time slot for initiating reservation  
5 of said plurality of scheduling modules per each frame at the  
leading end of each frame. The control data is data for realizing  
scheduling equalizing use frequency of reservation start slot  
for initiating said reservation by a plurality of scheduling  
modules. The control data is data for realizing scheduling  
10 equalizing use order and use frequency of reservation start  
slot for initiating said reservation by a plurality of scheduling  
modules.

According to another aspect of the invention, a packet  
switching method for determining connecting condition between  
15 input ports and output ports by making reservation for particular  
input port among a plurality of input ports for feeding data  
to a designated output port among a plurality of output ports  
in a scheduler of a switch having N in number of input port  
scheduling modules, comprising:

20 step of receiving reservation condition information of  
a certain time slot from the scheduling module in the preceding  
stage;

step of determining permission or rejection of reservation  
of packet transmission from said input port scheduling module  
25 in said reservation time slot, per time slot;





at the leading end of the frame, being progressed simultaneously in pipeline process, and completing simultaneously at the end of the frame;

step of initiating process for respectively different  
5 reservation time slot in the next frame in each of a plurality of said reservation processes which are initiated simultaneously at the leading end of the frame; and

reservation order varying step of varying order of said reservation by said plurality of scheduling module, and making  
10 reservation of ports to output with respect to a packet for next frame per each frame in the varied order.

The plurality of scheduling modules performs said reservation in an order corresponding to logical connection order relative to other modules, said reservation order varying  
15 means varies a connection topology of said plurality of scheduling modules. A plurality of scheduling module performs reservation in the order corresponding to the logical connection order with other modules. In variation of the reservation order, a plurality of scheduling modules varies connection topology.

20 The reservation order varying means includes a switch performing switching operation for varying logical connecting condition of said plurality of scheduling modules and a table storing control data for controlling switching operation of said switch. The physical connection between said plurality  
25 of scheduling module and said switch is an electrical connection

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or optical connection. The table is provided in each of said plurality of scheduling modules. In the alternative, the table is provide in common for said plurality of scheduling modules.

The control data is data for controlling switching  
5 operation of said switch for varying time slot for initiating reservation of said plurality of scheduling modules per each frame at the leading end of each frame. The control data is data for realizing scheduling equalizing use frequency of reservation start slot for initiating said reservation by a  
10 plurality of scheduling modules. The control data is data for realizing scheduling equalizing use order and use frequency of reservation start slot for initiating said reservation by a plurality of scheduling modules.

In short, the present invention realizes the input buffer  
15 type packet switch includes a virtual output queue as input buffer construction and the cross-bas switch as data switch element. Then, each module determines connection information of the input port and the output port of the cross-bas switch of certain time slot with respect to the connection request  
20 from each VOQ.

As set forth above, there are two unfairness in the RRGs and the framed RRGs. Namely, at first, as common program of the RRGs and the framed RRGs is unfairness in terms of connection reservation chance between adjacent ports (first unfairness).  
25 On the other hand, secondary, a problem relating to the framed

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RRGS for unfairness in terms of process delay in the same frame up to the connection grant response for the connection request between the ports (second unfairness).

Therefore, in the present invention, in order to resolve  
5 the first unfairness, the present invention takes a construction which permits variation of the connection topology between the modules. As apparatus, the reserved output port information transferred between the modules is input to the switch out of the module to vary the destination of output. The module and  
10 the switch operates in synchronism with the frame by performing connection grant process of a plurality of time slot for varying the connection topology per frame so that all connection topology may appear.

By varying connection topology, various combinations of  
15 adjacent ports appear to shuffle preference which is otherwise held in fixed condition. Thus, unfairness in terms of reservation chance of the input port can be resolved, Also, by preparing only patterns of particular connection topologies or by varying ratio of application of respective patterns with  
20 weighting application frequency of the pattern, it can realize control for increasing frequency of preferentially assigned port for particular input port or a plurality of particular input ports.

In order to solve the second unfairness, the process order  
25 of the reservation time slot in the process frame in the module

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Fig. 8 is an illustration of an example of the internal construction of a switch of Fig. 1;

Fig. 9 is a block diagram showing a construction of the second embodiment of the packet switch according to the present invention;

Fig. 10 is an illustration showing an order of reservation (determination of connection grant) of each module in the second embodiment of the packet switch according to the invention;

Fig. 11 is an illustration showing a typical construction of an input buffer type packet switch using VOQ;

Fig. 12 is an illustration showing a typical construction of the packet switch;

Fig. 13 is an illustration showing a determination method of the connection grant information of a framed RRGs; and

Fig. 14 is an illustration showing an order of reservation (determination of connection grant) in each module in the conventional framed RRGs.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will be discussed hereinafter in detail in terms of the preferred embodiment of the present invention with reference to the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be obvious, however, to those skilled in the art that the present invention may be practiced without

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these specific details. In other instance, well-known structure are not shown in detail in order to avoid unnecessary obscurity of the present invention.

It should be noted that in the following disclosure, like components to those set forth above will be identified by like reference numerals to omit detailed description thereof in order to avoid redundant discussion and whereby to keep the disclosure simple enough to facilitate clear understanding of the present invention.

Referring to Fig. 2, there is illustrated a type of connection topology of each module in the first embodiment of the present invention. The shown embodiment provides a solution for the first problem set forth above. The shown embodiment has been disclosed in terms of the system having four ports ( $N = 4$ ). Number of connection topologies in the case where number of ports is  $N$ , becomes circular permutation and thus becomes a factorial of  $(N - 1)$  ( $(N - 1)!$ ). The scheduler prepares  $(N - 1)!$  of connection topology patterns and uniformly generates respective topology pattern to vary connection of module to resolve unfairness concerning port reservation between adjacent modules. In case of the shown embodiment,  $(4 - 1)! = 6$  connection topology types are present. These six connection topology types are generated uniformly to vary connection of modules.

It is assumed that the logical module numbers are  $a$  to  $d$  and actual module numbers are 1 to 4. The reserved output

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port information is transferred in the order of  $a \rightarrow b \rightarrow c \rightarrow d \rightarrow a$  in the logical module numbers. Assignment of the actual module numbers in the six connection topology types is as shown in Fig. 2. For example, in Type #1, the logical number of the module of the physical number 1 is a, the logical number of the module of the physical number 2 is b, the logical number of the module of the physical number 3 is c, and the logical number of the module of the physical number 4 is d.

Referring to Fig. 3, there is shown an order of reservation (determination of connection grant) of each module as one embodiment of the present invention. What are represented by the vertical axis, the horizontal axis and the figures in the matrix are the same as those in Fig. 14. The example shows the case where the number of ports  $N = 4$ . A plurality of time slots form a frame. In the shown embodiment, one frame is consisted of four time slots. On the other hand, a plurality of frames form a super frame. For six frames from frame 1 to frame 6, the connection topology types 1 to 6 are applied. These six frames are combined to form the super frame. By applying the six connection topology types in order per frame, unfairness concerning port reservation between adjacent modules can be resolved. It should be noted that each frame is exemplarily illustrated with connection grant information reservation start pattern, in which the reservation start time slot of the logical number a is 1, b is 4, c is 3 and d is 2 (this is referred to

Referring to Fig. 1, there is shown a construction of the first embodiment of the scheduler according to the present invention. The shown embodiment is also illustrated for the case where the number of port is four ( $N = 4$ ). The scheduler 1 is constructed with the modules 10-1 to 10-4 in number corresponding to number of ports, and a switch 30.

The module 10-i has a function for determining connection grant by performing negotiation of the connection request and outputting the connection grant information 12 and the updated reserved output port information 14. Each module input the reserved output port information 14 and a switch information 20 to the switch 30. The switch 30 is responsive to the switch information 20 to performing switching for the reserved output port information 13 to output to respective modules.

Here, an example of construction of respective module

25 10-i in Fig. 1 will be discussed with reference to Fig. 4.

5           The allocator 15 determines the connection grant  
information 12 of the output port for the input port managed  
by the module on the basis of the connection request information  
11 and the reserved output port information 13. Algorithm to  
be used for determination of the connection grant information  
10 12 may be known algorithm.

The connection grant storage control portion 17 determines reservation order pattern of the connection grant information in the module from the reservation order pattern of the connection grant information from the pattern storage portion 18 and the physical number 23 for module identification, in synchronism with the frame pulse 21 for controlling order of writing and reading of the connection grant information 12 per time slot. The connection grant storage control portion 17 is constructed with a writing address counter 170 for generating a writing

5           The load data generating portion 172 determines a connection grant information reservation start value from the connection grant information start pattern, connection topology type and the physical number 23. The writing address counter 170 takes the connection grant information reservation start value as a load data and takes the frame pulse as a load input (Load). On the other hand, the reading address counter 171 takes the frame pulse as the load input (Load). These counters 170 and 171 performs counting operation in response to a not shown clock which takes the time slot period as one period. Then, 15 the counted values are input to the memory 160 in the connection grant storage portion 16 as the writing address and the reading address to perform writing and reading operation of the connection grant information.

The pattern storage portion 18 stores pattern information for determining the output order pattern of the connection grant information 12. As shown in Fig. 6A, the pattern storage portion 18 is constructed with incorporating a pattern table 180 which takes a pattern number as input and takes the connection topology type and the connection grant information reservation start pattern as outputs. Referring to Fig. 6B, there is illustrated

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101 to 104 select mutually different inputs. From ports OS1UP to OS4UP, the reserved output port information 13-1 to 13-4 held in the F/Fs 101b, 102b, 103b and 104b are output.

In Fig. 8, respective F/Fs operate in synchronism with the system clock applied to a port ISYSCLK. On the other hand, in Fig. 8, in response to a reset signal applied to a portIRSTB, respective F/Fs become clear condition.

In the switch 30 constructed as set forth above, four kinds of reserved output port information output from respective modules 10-1 to 10-4 are respectively input to 4:1 selectors 101 to 104. In respective selectors 101 to 104, one kind of reserved output port information is selected and output. The selected reserved output port information is input to respective modules 10-1 to 10-4.

Next, operation of the shown embodiment of the scheduler will be discussed when each module 10-i performs reservation process of the port according to the order of Fig. 3.

The frame pulse 21 is input in four time slot period and the super frame pulse 22 is input in six frame period (twenty-four time slot period). In the time slot 1 of the frame 1 of Fig. 3, the module 10-i shown in Fig. 4 is input the frame pulse 21 and the super frame pulse 22. In response to this, the pattern read out control portion 19 sets the connection topology of Fig. 2 from the pattern storage portion 18 to the connection grant storage control portion 17. On other hand, the pattern

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5 For example, the module 10-1 set "1" in the physical number  
23 selects the pattern of physical number 1 and frame 1 in the  
reservation order of the connection grant information of Fig.  
3.

Upon completion of the frame 1 of Fig. 3, the connection grant information 12 in four time slots of the frame 2 are fixed and stored in the connection information storage portion 16 in Fig. 4. Respective modules 10-1 to 10-4 of Fig. 1 read out the connection grant information 12 from the connection information storage portion 16 in Fig. 4 depending upon the time slot using the determined connection grant information in the time slots 1 to 4 of the frame 2 of Fig. 3 to notify to the cross-bar switch and the input port to perform switching of data.



Simultaneously with notification of the connection grant information, determination of the connection grant information of the next frame is performed. When the frame pulse 21 is input in the time slot 1 of the frame 2 of Fig. 3, the pattern read out control portion 19 in Fig. 4 sets the connection topology 2 of Fig. 2 from the pattern storage portion 18 to the connection grant storage control portion 17. On the other hand, the switch information of the connection topology type 2 is output from the pattern read out control portion 19. Each module 10-i selects the reservation order pattern of the connection grant information in the current frame from the physical number 23 and the set connection topology type 2 for identifying the own module.

The switch 30 in Fig. 1 performs switching so that the connection of the reserved output port information from respective modules 10-1 to 10-4 becomes as the connection topology of Fig. 2 on the basis of the switch information 20 from the modules 10-1 to 10-4. Respective modules 10-1 to 10-4 implements reservation according to the connection grant information reservation order in the case of the connection topology 2 in the zone of the frame 2 of Fig. 3. Similarly, switching of the connection topology, reservation for the next frame, and notification of the connection grant information are performed. After execution of reservation by the connection topology of the type 6, the frame pulse 21 and the super frame

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pulse 22 are input. The module 10 then returns the connection topology type to the type 1 to continue reservation process.

As set forth above, the connection topology is switched between respective modules 10-1 to 10-4 by the switch 30 to  
5 make all of the connection topology to appear uniformly to shuffle the preference of the chance of reservation of the input port which has been fixed otherwise, to resolve unfairness associating with the chance of making reservation of the input port.

10 In the first embodiment set forth above, discussion has been given for the embodiment in which the switch information for switching the reserved output port reservation information is notified from respective modules 10-1 to 10-N. By this, the packet switch can be easily formed by forming respective modules  
15 10-i in identical construction with each other, inputting the frame pulse 21 and the super frame pulse 22 to respective modules, and by externally inputting the physical number 23 for identification of the module. As set forth above, since respective modules may have the identical construction, it is  
20 suitable for mass production and whereby to lower cost. It is also considered an embodiment, in which the switch information is notified to the switch 30 from a particular module 10-k ( $k$  is natural number and  $1 \leq k \leq N$ ).

On the other hand, as a method for reading out the connection  
25 topology pattern by the module 10-i, there is a method to use

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Furthermore, in the foregoing embodiment, the reservation order pattern of the connection topology type and the connection grant information are renewed in synchronism with the frame pulse 21 with establishing synchronization of the variation order of the connection topology type of respective module 10-i by inputting the frame pulse 21 and the super frame pulse 22 in the module 10-i. In addition to, it is considered another construction to externally input the connection topology and the reservation order pattern of the connection grant information, to each of modules 10-i. Namely, as shown in Fig. 9, it may be accomplished by providing an information generating portion 140 generating the connection topology type and the reservation order pattern. However, for establishing synchronization, it is required to input the frame pulse 21 and the super frame pulse 22 to the information generating portion 140 through a not shown signal line.

It should be noted that while in the first embodiment, the all connection topology patterns are generated uniformly, it is possible to increase appearance of particular connection topology. In such case, it is effective to enhance preference concerning chance of making reservation for the particular input

Next, the second embodiment of the present invention will be discussed. Fig. 10 shows an order of reservation (determination of connection grant of the module 10-i in the second embodiment. The shown embodiment provides a solution for the second problem in the prior art as set forth above.

In Fig. 10, the contents of the vertical axis, the horizontal axis and the figures in the matrix are the same as those in Fig. 14. The shown embodiment has been illustrated in the example where number of ports is four ( $N=4$ ). A frame is consisted of a plurality of time slots. In the shown embodiment, since number of the ports is four, one frame is consisted of four time slots. On the other hand, the super frame is consisted of a plurality of frames. When number of ports is  $N$ , number of cases of the time slots to initiate reservation at the leading end in the frame by the module 10-i (which number of cases will be referred hereafter as "phase type"). is  $N$ . It should be noted that every frames are illustrated in Type #1 of the connection topology pattern. Namely, the logical module number of the module having physical number 1 is a, the logical module number of the module having the physical number 2 is b, the logical module number of the module having physical number 3 is c and the logical module number of the module having the physical number 4 is d.

In case of the shown embodiment, as phase types, there

are four phase types i.e. Type #A to Type #D. In the Type #A, the reservation start time slot of the logical module number a is 1, the reservation start time slot of the logical module number b is 4, the reservation start time slot of the logical module number c is 3 and the reservation start time slot of the logical module number d is 2. Accordingly, the reservation start time slot of the physical number 1 is 1, the reservation start time slot of the physical number 2 is 4, the reservation start time slot of the physical number 3 is 3 and the reservation start time slot of the physical number 4 is 2. For the frames 1 to 4, the phase types A to D are applied respectively. Combining these four frames, the super frame is formed. By applying the four phase types to respective frames in sequential order, unfairness in terms of delay between respective modules can be resolved.

The overall construction of the shown embodiment of the scheduler according to the present invention is similar to the construction illustrated in Fig. 12. Here, it should be noted that respective modules 10-1 to 10-4 in Fig. 12 are replaced with those illustrated in Fig. 4.

In each module 10-i, the frame pulse (FP) indicative of the leading end of the frame and the super frame pulse (SuperFP) indicative of the leading end of the super frame are input. The switch information 20 of the module 10-i is not used in the shown embodiment.

15 information per phase pattern shown in Fig. 10.

time slots period).

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Each module 10-i performs scheduling by the framed RRGs according to order of scheduling in the case of the phase type A in the zone of frame 1. Upon completion of the frame 1 in Fig. 10, the connection grant information in the four time slots of the frame 2 are fixed and stored in the connection information storage portion 16 in Fig. 4. Each module reads out the determined connection grant information 12 from the connection information storage portion 16 in Fig. 4 over the time slots 1 to 4 of the frame 2 to notify to the cross-bar switch and the input ports for executing data transfer.

At the same time of notification of the connection grant information, determination of the connection grant information of the next frame is performed. In the time slot 1 of the frame 2 in Fig. 10, the pattern read out control portion 19 shown

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5 same as the first embodiment can be realized.

10 portion 18 in the order which is desired to be applied.

15 the phase type and the reservation order pattern of the connection grant information are updated. Similarly to the first embodiment, it may be considered to externally input the phase pattern and the reservation order pattern of the connection grant information.

20 Furthermore, while the all phase patterns are generated uniformly in the shown embodiment, it is also possible to increase frequency of appearance for the particular phase pattern to make the particular input port to reduce the average delay.

It should be noted that, in the construction of the first  
25 embodiment, fairness in terms of the average delay and fairness

in reservation chance of the input port can be realized simultaneously.

The connection topology of the module 10-i corresponds to the case where the phase of the reservation start time slot is fixed. Discussing with reference to Figs. 3 and 10, when number of ports N is 4, six kinds of reservation order in each module corresponds to the case of implementation of modification of connection in the phase type A as shown in Fig. 10. Accordingly, in case of the types B, C and D of Fig. 10, considering the pattern for which variation of connection is performed, twenty-four kinds of patterns are present. This is nothing but permutation of the module in the scheduler 1. Namely, the direct product (multiplication) of the connection topology type of the module and the phase type of the reservation start time slot becomes the permutation of the module.

In the construction of the first embodiment, by storing the permutation of the module (twenty-four kinds) in the pattern storage portion 18 storing the connection topology, in place of the connection topology (six kinds), and by inputting the superframe pulse 24 in a period of integer multiple of twenty-four frames (ninety-six time slots) to perform twenty-four kinds of reading out by the pattern readout control portion 19, fairness of the reservation chance of the input port and fairness of the average delay can be resolved simultaneously. Referring to Fig. 6D, the content of the pattern table 180 in a further

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5 correspondence to pattern number 0 to 23.

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10 reservation chance of the input port.

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15 fixed, can be varied to realize equalization of the average

20 additions and different designs without departing from the

25 without departing from the principle of the invention set forth

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